Government Publications

SI Ont. [G-7] metric system

Hydro-Electric Power Commission [General publications]

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introduction

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This booklet has been designed as an introduction to the metric system of international units.

As a major trading nation Canada is interested in the metric system and inevitably as more countries convert to this system, Canadian industry will be affected.

Ontario Hydro is attentively following developments in this field and at present makes use of the metric system in its nuclear-electric program.

the SI metric system

Man uses precise standards of measurement to examine the physical universe with a high degree of accuracy and as a basis for all technology.

In an ideal system of measurement a few precise units would be reproduced anywhere with high accuracy. The closest approach to this goal is the Système International (SI) — the International System of Units — which has been widely adopted around the world. The four basic SI building blocks are length, mass, time and temperature units on which all others depend. All but mass are now defined in terms of natural constants.

The SI system is more convenient and simpler for calculations than the foot-pound system. It uses multiples and sub-multiples of 10 for all units, such as the metre, gram, or the second. SI units have universal applications which span national and professional boundaries to improve communications.

In 1965, Britain decided to adopt the SI system over a 10-year period. As a result Canada and the U.S. are

becoming an isolated foot-pound island. An estimated 91 per cent of the world's population uses the metric system and 76 per cent of world production comes from metric countries. They include European nations, the Soviet Union, China, Japan and India.

Britain's decision to convert to the metric system has created wide interest in Canada and the United States and has led to demands for intensive studies of the economic impact of the metric system on their respective economies. Many observers predict that it's only a matter of time before these countries convert to the international system.

The Canadian Government has accepted eventual adoption of a single measurement system based on metric units as "inevitable and in the national interest."

SI use in hydro

Although the foot-pound system prevails in Canada, the metric system has been legal for more than 75 years. Metric units are widely used in science and medicine and by the photographic, optical, scientific instrument, pharmaceutical, electrical and nuclear industries. Ontario Hydro relies both on the foot-pound and metric systems; such metric terms as kilowatt, ampere, volt and hertz are in everyday utility use. The international system has a number of other Hydro applications and commands wide support, particularly among engineers and scientists.

Besides the normal Hydro applications, nuclear operations have been using metric terms for heavy water, fuel and physics calculations at nuclear power stations.

Preparations are now under way to make even more extensive use of SI units.

All instrumentation in the new 3 000-megawatt (net) Bruce nuclear power station will be calibrated in SI units or units acceptable to the SI System. Steam pressures will be measured in pascals, temperatures in degrees Celsius*, mass flows in kilograms per second and volume flows in cubic metres per second. SI units will be used for commissioning the Bruce station and usage will be universal for operation of this plant by the time first power is produced in 1975.

As a first step in conversion to SI units, a technical manual containing conversion tables has been prepared for the use of Hydro personnel and others in the nuclear industry. The manual will serve as a practical guide to the application of SI units in Hydro's nuclear power stations.

SI defined

The development of a unit of length illustrates the transition from a crude to precise, reproducible measurement. As the story goes King Henry I established the yard as a unit of measurement by surveying the distance from the tip of his nose to the end of the thumb of his outstretched hand. In the 18th century, French scientists defined a new

*The Celsius scale for temperature, previously called centigrade, was proposed in 1742 by Anders Celsius of Sweden. The kelvin, named for Lord Kelvin, is now equivalent to the term "degree Celsius"; however the scales differ in their zero point; 273.15K is equal to 0°C.

unit, the metre, as a particular fraction of the earth's dimension between Dunkirk and Barcelona. But in 1960 the General Conference of Weights and Measures* redefined the metre in terms of a particular wavelength of radiation from the isotope krypton 86.

The unit of time, the second, and of temperature, the kelvin, have been redefined in terms of natural constants as shown in the accompanying table. Only the kilogram, which was originally defined as a mass of one cubic decimetre (1 000 cubic centimetres) of water at its maximum density (277 kelvin), has no reference point in nature. It is now based on the mass of Prototype Kilogram No. 1 kept at the International Bureau of Weights and Measures at Sèvres, France. Because copies of the prototype are accurate to one part in 100 million, little effort is being made to produce another standard.

* The International Bureau of Weights and Measures was founded by treaty in 1875, with permanent headquarters at Sèvres, France. Its purpose is to assure "the international unification and improvement of the metric system." General Conferences are meetings of the signatory nations. An international committee supervises the Bureau between meetings.

basic SI units

These four quantities are the building blocks of the International System of Units. From them, all units needed to express the magnitudes of the many properties measured in science and technology can be derived. *

length
metre

1 650 763.73 wavelengths in vacuum of transition between energy levels $2p_{10}$ and $5d_5$ of krypton-86 atom, excited at the triple point of nitrogen (—210 degrees Celsius).

mass
kilogram

Mass of Prototype Kilogram No. 1 kept at International Bureau of Weights and Measures at Sèvres, France.

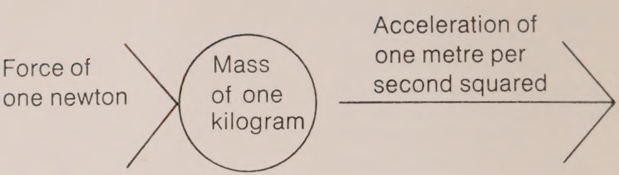
*Two additional derived units are needed to completely define the SI System — the ampere for electric current and the candela for light intensity.

time
second

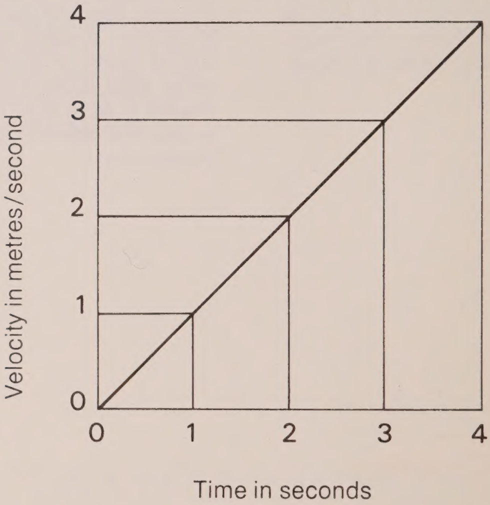
9 192 631 770 cycles of frequency associated with the transition between two hyperfine levels of isotope cesium 133.

temperature
kelvin

1/273.16th of the thermodynamic temperature of the triple point of water, which is 273.16 kelvin. At this temperature, solid, liquid and vapor phases of water exist together in their respective states at equilibrium.



If a mass of one kilogram has zero initial velocity, its velocity increases with time as indicated in the following graph:



selected derived SI units

force
unit: newton

The force which gives to a mass of 1 kilogram an acceleration of 1 metre per second squared.

pressure
unit: pascal

The pressure given by a force of 1 newton applied to 1 metre squared.

energy
unit: joule

Work done by 1 newton through 1 metre.

power
unit: watt

Production of energy at 1 joule per second.

volume (capacity)
unit: litre

The volume of one one thousandth of a metre cubed.

frequency
unit: hertz

The frequency of one cycle per second.

electricity
unit: ampere

(Unit of electric current) is the constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular sections, and placed 1 metre apart in a vacuum, will produce between these conductors a force equal to 2×10^{-7} newton per metre of length.

unit: volt

(Unit of electric potential difference and electromotive force) is the difference of electric potential between two points of a conducting wire carrying a constant current of 1 ampere, when the power dissipated between these points is equal to 1 watt.

unit: ohm

(Unit of electric resistance) is the electric resistance between two points of a conductor when a constant difference of potential of 1 volt, applied between these two points, produces in this conductor a current of 1 ampere, this conductor not being the source of any electromotive force.

unit: siemens

(Unit of electric conductance) is the electric conductance between two points of a conductor when a constant difference of potential of 1 volt, applied between these two

points, produces in this conductor a current of 1 ampere, this conductor not being the source of any electromotive force.

unit: coulomb

(Unit of quantity of electric charge) is the quantity of electric charge transported in 1 second by a current of 1 ampere.

unit: farad

(Unit of electric capacitance) is the capacitance of a capacitor between the plates of which there appears a difference of potential of 1 volt when it is charged by a quantity of electric charge equal to 1 coulomb.

unit: henry

(Unit of electric inductance) is the inductance of a closed circuit in which an electromotive force of 1 volt is produced when the electric current in the circuit varies uniformly at a rate of 1 ampere per second.

unit: weber

(Unit of magnetic flux) is the magnetic flux which, linking a circuit of one turn, produces in it an electromotive force of 1 volt as it is reduced to zero at a uniform rate in 1 second.

multiples and sub-multiples

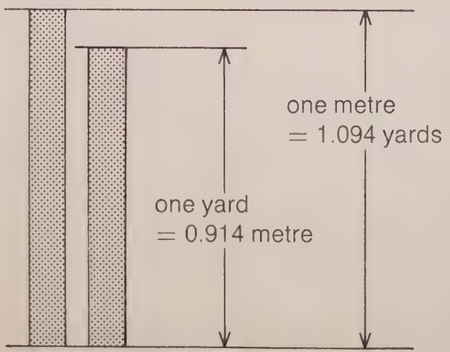
this table shows the internationally agreed multiples and sub-multiples of the basic SI units.*

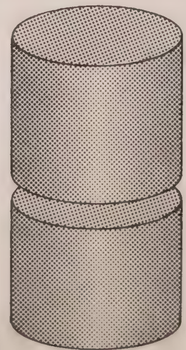
factor by which unit is multiplied		prefix	symbol	examples
one million million (British billion)	10^{12}	tera	T	terawatt (TW)
one thousand million (U.S. - Canada billion)	10^{9}	giga	G	gigahertz (GHz)
one million	10^{6}	mega	M	megawatt (MW)
one thousand	10^{3}	kilo	k	kilometre (km)
Unity	1			

one thousandth	10^{-3}	milli	m	milligram (mg)
one millionth	10^{-6}	micro	μ	microsecond (μs)
one thousand millionth (U.S. - Canada billionth)	10^{-9}	nano	n	nanosecond (ns)
one million millionth (British billionth)	10^{-12}	pico	p	picofarad (pF)
one thousand million millionth	10^{-15}	femto	f	femtofarad (fF)
one million million millionth	10^{-18}	atto	a	attometre (am)

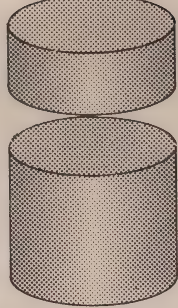
*The submultiples centi (10^{-2}) and deci (10^{-1}) and to a lesser extent the multiples deca (10^{1}) and hecto (10^{2}) are in common use, but are not recommended by the International Organization for Standardization.

some graphic comparisons of the basic SI units with foot-pound units



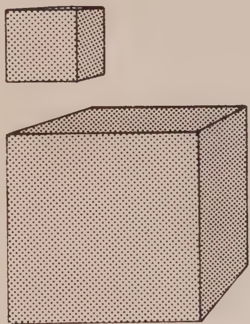


	Celsius	Kelvin	Fahrenheit
water boils	100°C	373.15K	212°F
human body temperature	37°C	310.15K	98.6°F
water freezes	0°C	273.15K	32°F



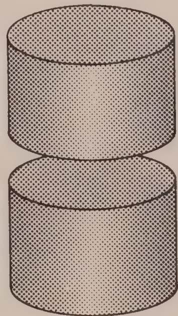
one pound
= .454 kilogram

one kilogram
= 2.205 pounds



one foot cubed
= 0.028 3 metre
cubed

one metre cubed
= 35.3 feet
cubed



one ton
= 0.907 megagram
(tonne)

one megagram (tonne)
= 1.102 tons

the search for better constants

Although as presently defined the SI system represents a major accomplishment in establishing universal standards of measurement the search for improvement goes on. For example, the chief defect of the krypton standard for the metre is that it still cannot be used for measuring distances as long as a metre in a single step. Development of the laser, however, opens up the possibility of measuring differences of tens or hundreds of metres rather than centimetres.

Another goal is a more accurate timepiece. The cesium clock now used has an accuracy of about one part in 10^{12}, which means that in 6 000 years it would not gain or lose more than a second. The U.S. National Bureau of Standards is working on a still more accurate device, such as the hydrogen maser, which promises to be 100 times more accurate than the cesium clock.

Efforts are also being made to measure temperature extremes which have become increasingly important in many technologies. For example, liquid oxygen chilled to about 90K is used as an oxidizer for rocket fuel and researchers are investigating supercold liquid hydrogen (20K) as an insulator for underground power cables to overcome resistance to the flow of electric current. At the other extreme attempts are being made to achieve the fierce temperatures necessary to fuse hydrogen atoms and release controlled energy to produce electricity.

But extensions of the temperature scale to these regions have proved difficult, particularly below 5K and above 10^7K associated with hydrogen fusion. New methods will be necessary to measure temperatures at these extremes accurately.

selected conversion factors

To convert foot-pound units to metric units multiply by the red factor.

To convert from metric to foot-pound units multiply by the black factor.

unit	multiply by		unit
length			
inch	25.4	.039 4	millimetre
foot	0.305	3.28	metre
yard	0.914	1.094	metre
mile (statute)	1.609	0.621	kilometre
area			
inch squared	645	0.001 550	millimetre squared

foot squared	0.092 9	10.76	metre squared
mile squared	2.59	0.386	kilometre squared
volume			
ounce (Imperial fluid)	28.4	0.035 2	millilitre
pint (Imperial)	0.568	1.760	litre
quart (Imperial)	1.136	0.880	litre
gallon (Imperial)	4.55	0.220	litre
inch cubed	16.39	0.0610	millilitre
foot cubed	0.028 3	35.3	metre cubed
mass			
ounce	28.3	0.035	gram
pound	0.454	2.20	kilogram
ton	0.907	1.102	megagram (tonne)

conversion factors
continued

unit	multiply by		unit
force (weight)			
pound	4.45	0.225	newton
pressure			
pound/square inch	6.89	0.145	kilopascal
energy			
British Thermal Unit	1.055	0.948	kilojoule
temperature			
degree fahrenheit	5/9 and subtract 17.78	9/5 and add 32	degree celsius
degree fahrenheit	5/9 and add 255.37	9/5 and subtract 459.67	kelvin

NOTE: To convert from degrees celsius to kelvins, add 273.15. Subtract 273.15 for the opposite conversion.

ontario hydro

an explanation of current standards prepared by Ontario Hydro for employees

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